DIURNAL EVOLUTION OF ATMOSPHERIC STRUCTURE WITHIN METEOR CRATER, ARIZONA: IMPLICATIONS FOR MICRONICHES ON MARS. C. D. Whiteman[1], D. A. Kring[2], and S. W. Hoch[1] [1]Meteorology Department, University of Utah, 135 S 1460 E, Rm 819, Salt Lake City, UT 84112-0110, USA, dave.whiteman@utah.edu [2]Lunar and Planetary Institute, Houston, TX 77058-1113, USA, kring@lpi.usra.edu.

Introduction: Barringer Crater in Arizona is a potential earth analogue to Endurance and Victoria craters [1-3] presently being explored on Mars. Data from a meteorological experiment at Barringer Crater in 2006 [4] are analyzed to determine meteorological phenomena that may be present in the Martian craters.

METCRAX Experiment: Barringer or Meteor Crater [5] is a well-preserved bowl-shaped meteorite impact crater located in an arid climate 40 km east of Flagstaff. It is approximately 1.2 km in diameter, 180 m deep (rim to floor), and the crater rim extends 30-60 m above the height of the surrounding Colorado Plateau. Air temperature measurements on the crater rim and at the crater floor were collected at 10-min intervals from 28 Sep 2005 to 31 Oct 2006 to determine seasonal variations of temperature inversion strength inside the crater. Air temperature measurements were also collected at 5-min intervals during a 3-mo period ending on 31 Oct 2006 at 56 additional sites on E-W and N-S lines that met at the crater center and extended out onto the adjacent plain. The main observational period was 1-31 Oct 2006 when seven flux towers with multiple levels of wind, temperature, and humidity sensors were operated in and around the crater by NCAR. Eddy correlation turbulence sensors and radiometric instruments at these sites measured all components of the surface radiative and energy budgets. The towers were placed on an E-W line through the crater center with two towers on the east sidewall, one at the crater floor center, and three on the west sidewall (including one on the crater rim). A separate radiometric tower was operated on the crater floor to measure longwave radiative flux divergence. An additional flux tower, a SODAR, a Radar Wind Profiler, and two Radio Acoustic Sounding Systems were operated outside the crater to provide continuous vertical profiles of horizontal winds and temperatures to heights of up to 4 km. During seven 18-h-long Intensive Observational Periods (IOPs), when winds aloft were weak and skies were clear, three tethered balloon sounding systems inside the crater made frequent atmospheric soundings of wind, temperature and humidity to heights above the crater rim, while rawinsondes were released outside the crater at 3-hr intervals to collect similar data to heights of 20-30 km.

Results: The ongoing research program is examining boundary layer evolution inside the crater and its response to asymmetries in insolation on the sidewalls; the mean and turbulence characteristics of the up- and down-slope flows on the inner sidewalls of the crater; seiches and atmospheric gravity waves within crater temperature inversions; and the effects of ambient winds on the slope flows and temperature structure within the crater. Here we summarize the wind flow patterns and horizontal and vertical temperature field.

Wind structure. The crater atmosphere was strongly coupled to background flows, especially during daytime when horizontal-axis eddies were shed by the crater rim and large vertical-axis eddies formed over the crater floor. At night, the crater meteorology was affected by a large scale drainage flow from the higher terrain of the Mogollon Rim SW of the crater. This produced occasional mixing events (warm air break-ins) over the south and west sidewalls that, surprisingly, did not extend into the middle of the crater.

Shallow downslope drainage flows were observed in time lapse videos of dispersion from smoke grenades on the west sidewall and were seen in tower data. They were most prominent during a 1-2 hour period early in the inversion buildup period, but were intermittent for the remainder of the night. Such downslope flows are known from previous research to have a temperature deficit relative to air at the same height away from the slope and are channeled into topographic declivities such as sidewall gullies [6], which are a prominent topographic feature of Meteor Crater as well as Martian Craters [7].

Temperature Structure. The maximum daily temperature differences between the crater rim and floor (Fig. 1) over an annual cycle indicate the strongest temperature inversions occur in winter when temperatures increase by 15°C from the floor to the rim. The minimum daily temperature differences, shown on the same figure, are always negative indicating that nocturnal inversions are broken up on a daily basis, with no persistent multi-day temperature inversions.

Diurnal air temperature differences across the crater (Fig. 2) are created by shadows cast by the rim and the effects of differential insolation on the opposing sidewalls. At night when temperature inversions formed in the crater, the temperature differences between sidewalls at the same height became small. At the level of the crater rim, however, the SW rim could be 3°C colder than the NE rim when a large scale cold air drainage flow from the SW affected the crater. During daytime, temperature differences reached 4°C when one sidewall was in sunlight and the opposing sidewall was in shadow. The N and W sidewalls were relatively warmer in the morning and the E sidewall was relatively warmer in the afternoon.

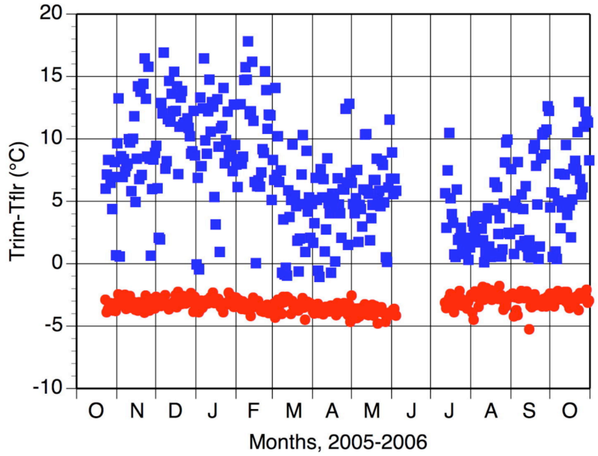

Figure 1. Daily maximum (blue) and minimum (red) temperature differences between the rim and floor of Meteor Crater from 22 Oct 2005 through 31 Oct 2006. Note missing data between 4 June and 11 July.

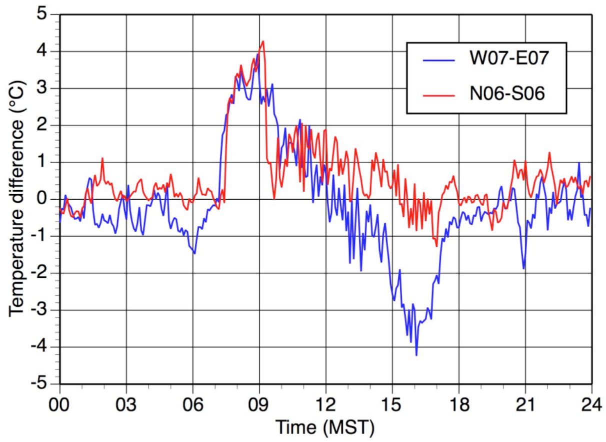

Figure 2. Temperature differences between opposing W, E, N and S sidewalls at about 75 m above the crater floor on 22 Oct 2006.

Temperature inversions formed in the crater in the late afternoon and evening during periods when the crater was undisturbed by strong background flows. Under inversion conditions, the temperature structure became approximately horizontally homogeneous across the crater from sidewall to sidewall. The inversion had an unusual vertical structure not seen in previous small basins. A 30-m-deep stable layer with temperature increase of about 5°C formed on the crater floor. This was surmounted, however, by a deep near-isothermal layer that extended to rim height, where it was capped by an elevated inversion that connected the cold air in the crater to the warmer air aloft. Several hypotheses are being tested to determine the processes that produce the unusual near-isothermal layer. The likely cause is vertical mixing by mesoscale cold air advection over the southwest rim of the crater, which rises only 30-60 m above the surrounding plain. The nocturnal inversion was destroyed within 2.5 hours after astronomical sunrise when a convective boundary layer grew upwards from the heated crater floor and sidewalls. The strong upward growth of this layer during daytime in this arid climate produces a deep convective boundary layer by late afternoon. The convection, which mixes down strong winds from aloft, is responsible for the strong gusty daytime winds for which Meteor Crater is well-known.

Lacustrine sediments on the crater floor indicate the presence of a lake during geological periods when the climate was more moist than at present. The lake, because of the differing thermal properties of water and soil, provides a moderating influence on nocturnal cooling and would be expected to moderate the strength of crater inversions, except when the lake was frozen. Its presence would not be expected to influence strongly the cold air drainage in gullies in the upper elevations of the crater.

Implications: Atmospheric composition and other characteristics differ between Earth and Mars, as do orbital characteristics. Nevertheless, some general comments can be made. Cold air may pond on crater floors at night, deepening the thermal inversion seen by MER [1]. These inversions may have been mitigated by crater lakes earlier in Mars history, but not if they were frozen. Daily temperature variation is greater and average temperature less on a crater floor than crater rim. Downslope winds may enhance ablation of volatiles from sidewall bedrock, caves, and talus, particularly where channeled through gullies. Condensation of volatiles is more likely on shadowed slopes and where large-scale nighttime drainage flows spill over a crater rim.

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